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From the very twilight of history men have endeavored to discover the causes of diseases ; and the record of the hypotheses that have at various times been held as solving the problem, constitute an interesting, albeit a saddening chapter in the history of human intelligence—saddening, because it is a record of so much ignorance, superstition and intolerance.

Commencing with a theistic idea, by which all disease was attributed to the wrath of some outraged deity, the general theory of a supernatural origin for maladies can be traced through successive ages even to our own time ; for it appeared in the blind fatalism that but a few weeks since caused a riot in Tashkend, one of the chief cities of Turkestan, over sanitary efforts to stay the progress of the devastating cholera. The many ways in which the deities of the polytheistic mythologies might be offended, gave a ready excuse to people who were unwilling or unable to admit that their own filthy habits had anything to do with the course of an epidemic. Homer sings that the plague that laid desolate the Grecian camp before Troy was due, not to the lack of proper sanitary precautions, but to the anger of Apollo, because of an insult to his priest.

“The favoring power attends,
And from Olympus’ lofty top descends ;
Bent was his bow, the Grecian hearts to wound,
Fierce as he moved, his silver shafts resound.
Breathing revenge, a sudden night he spread,
And gloomy darkness roll’d about his head.
The fleet in view, he twang’d his deadly bow,
And hissing fly the feathered fates below.
On mules and dogs the infection first began ;
And last the vengeful arrows fix’d in man.
For nine long nights, through all the dusky air,
The pyres, thick-flaming, shot a dismal glare.”

—Pope’s *Iliad*, Bk. I, Lines 61-72.



With the monotheism of the Hebrews, and their doctrine of a divine code, diseases, especially epidemics, were traced, not to the whim or caprice of some half human being, but to the punishments of a just and unerring God for infringements of his laws. The Jewish history bore out this theory, for the murrain in Egypt was the result of the direct interference of their God, and the disastrous results following the violation of their law, much of which was sanitary, was thought to be a manifestation of the same Almighty will.

In accordance with that tendency of the human mind to materialize or personify an abstract idea, diseases were looked on, at a later period, as a species of ogre, waiting to pounce upon the unsuspecting victim. Traces of this feeling are still perceptible in the common expressions, "attacks" of fevers, apoplectic "seizures," and such phrases; but with the interest in anatomy and physiology that arose in the fourteenth and fifteenth centuries, a new view came into existence, the supporters of which held that diseases were due to disordered conditions of the "humors" of the body, a hypothesis doomed to destruction with increased physiological knowledge. This knowledge, however, produced a school that attributed all diseases to various peccant organs, especially to those of whose functions but little was known. The spleen thus came in for far more than its share of human woes, and the bile was charged with crimes sufficient to make one ashamed of owning an organ capable of secreting such a monster. Even to-day the ills attributed to intestinal worms are more numerous and grievous than those which a political party ascribes to the rule of its opponent.

This hypothesis was productive of good results, for by its influence, aided by the introduction of the microscope and the close study of pathological anatomy that it stimulated, a vast store of facts and observations was laid up for future generations.

But the most painstaking observation of a burning house, or of the ruins of one destroyed by fire, will prove of little utility in stopping or preventing a conflagration if the nature and origin of fire itself remain a mystery; and so it is evident that

the closest investigation of an organ already diseased can do but little toward the elucidation of the great problem of disease. Aid was to come from an unexpected source.

This source was the studies based on the investigation of *fermentation*. The phenomenon of fermentation had been observed from the earliest times. Moses makes a difference between leavened and unleavened bread, and states that in their flight from Egypt the Israelites had not time to put leaven in their bread. Even in more remote antiquity, Noah is cited as having put alcoholic fermentation to an actual test, but though of this respectable age, only two facts are recorded as having been observed in regard to it. Of these, the first is, that a peculiar substance (called a ferment) must be added to the fermentable material; and the second is, that this ferment is capable of increasing itself. "A little leaven leaveneth the whole lump." The nature of this ferment was unknown, and continued so till 1680, when Leuwenhœck examined beer-yeast microscopically, and ascertained that it was composed of small globular bodies, the precise character of which he could not determine. Since that time, the researches of many students, especially those of Pasteur of Paris, in our own time, have shown that yeast is a plant belonging to an order that, on account of its action on sugars, has been called the *saccharomyces*.

As a result of these investigations, and of the increased interest in biology that arose in the latter half of this century, other micro-organisms have received great attention, particularly those to which the generic name of *Bacteria* has been given, and from this study most valuable results have come. The term bacteria was originally applied to a single class of micro-organisms, and strictly it still is so used; but in ordinary usage, it is generic, and will be used as such in this paper. The effect of these bacterial studies is well summed up by Senn, in the introduction to his work on *Surgical Bacteriology*, thus: "During the last fifteen years there has been more real advance made in surgical pathology than during twenty centuries preceding them. Bacteriology opened a new era for surgical pathology. The knowledge which has accumulated from the bacteriological

investigation of disease has opened new fields of usefulness for the surgeon. Many diseases hitherto treated uselessly with drugs by the physician are now successfully treated by surgical measures. At this time surgical pathology has almost become synonymous with surgical bacteriology."

Such being the case, it is highly important that something be known by every one of the well-established facts of this subject.

With this in view, it will not be out of place to consider the various ways in which the bacteria affect a higher organization. These ways may be roughly divided into two classes—one, in which the bacterium directly attacks and destroys the tissue in which it has obtained lodgement; and another, in which a by-product of the life of the micro-organism is the agent that immediately does the damage. Thus, in inflammation followed by pus formation, the pyogenic bacteria are probably directly responsible; but in tetanus the active poison is an alkaloidal product, or a mixture of such products, resulting from the life of the bacillus tetanus. These alkaloidal products may be isolated, and are as certain to produce tetanus, if introduced in sufficient quantity into the system, as morphia is to produce its physiological effects.

But in addition to the bacteria that are always pathogenic, there are others that are only so at times. In other words, some bacteria which normally are not capable of causing disease, may, under peculiar environment, acquire malignancy and be pathogenic. Conversely, some bacteria that are violently malignant, may, by cultivation in an unsuitable medium, become attenuated, so that, on inoculation, a very mild type of the disease will follow, sometimes only a local manifestation. There is reason to think that "comma" bacillus of Asiatic cholera exhibits these variations of malignancy. The environment producing these variations may be the soil in which the micro-organisms are grown—the temperature, the presence or absence of oxygen, and some conditions as yet unknown. The diet on which the subject of the experiment has subsisted has a marked influence. In the Bradford epidemic of anthrax, this was shown by a curious fact. It was noticed that the majority of cases among the

wool-sorters occurred on Sunday, or between Saturday and Monday. This was holiday season, as the mills were closed during that time, and much curiosity was aroused to discover what excited the dormant bacilli at that time. It had been found that the herbivorous animals were peculiarly liable to attacks of this disease, and that it was difficult, if not impossible, to produce it in carnivorous animals. Investigation showed that the wool-sorters ate largely of vegetables during their brief holiday, and thus rendered themselves easier prey to the disease. The bacillus of mouse septicæmia is rapidly fatal to the house mouse, but is harmless to the field mouse. Here we have two animals of the same species responding to the same agent differently because of their different diet. Similarly rats vary in susceptibility as they are fed on vegetable or animal diet. Some bacteria seem to depend on the secretions of other varieties for malignancy, as, united, they are malignant; divided, they are harmless. These varieties greatly complicate the study of bacteriology and impede our progress toward a complete comprehension of the subject.

Before considering the separate bacteria, it may be well to state briefly the modes by which the different species are differentiated. These are—(1) direct microscopical examination, (2) the appearance of the “culture” in the tubes or other receptacle, (3) the behavior of the bacteria or their products with chemical re-agents, and (4) the results of inoculations practiced on animals.

1. The first of these, *direct examination*, is when unaided by any of the others, of relatively little importance, as but few varieties possess such morphological peculiarities as to render them recognizable. Of course it makes out the distinction between the cocci and the bacilli—the one appearing as minute dots or spheres, the other as little rods. The cocci, in turn, can be divided into the streptococci, which appear as rows of little dots; the diplococci, which are in pairs; and the staphylococci, which are clustered in groups. The bacilli give less scope for morphological classification. Some are curved, as is the comma bacillus; some are short, with clubbed ends, as is the bacillus

typhosis; some bear a spore on one end, as the bacillus tetanus; some are motile, as the bacillus of relapsing fever; but, on the whole, mere inspection would enable one to differentiate but few species.

2. The *appearance of the cultures* is somewhat more satisfactory; indeed, some varieties have received names from the appearance of their cultures. They may or may not liquefy the medium in which the growth takes place; the growth may be visible on some soils and invisible on others, as the bacillus typhosis, which is visible in gelatine, but not so on potato. In some cases in which the active agent causing a disease has not been made out, it has at least been settled that it does not belong to a certain one of these classes. Thus Sternburg,* although he has not definitely determined the bacterium of yellow fever, has made out that it does not liquefy gelatine when access of air is permitted. Certain varieties, as the bacillus fluorescens, have a peculiar color re-action; others produce nodules, thick or delicate cloud-like masses, spicular or branched growths, and some few have a characteristic odor.

3. *The behavior of the bacteria in relation to certain chemical re-agents* is frequently very characteristic. Bujwid† asserts that if to a ten-hour old culture of Koch's comma bacillus five or ten per cent. hydrochloric, nitric or sulphuric acids, be added, a rose-violet color is produced, which gradually grows more intense in the course of half an hour. This "cholera-red" is, so far as I am aware, unique.

The re-actions with aniline dyes are of more practical importance. As a rule, the mineral acids decolorize objects stained with these dyes, but it is possible to fix the stains in certain bacteria by mordants of different kinds, so that everything else in the specimen will be decolorized but the special bacterium. Erlich's familiar stain for tubercle is an instance of this. He uses a solution of aniline oil in water as a mordant for gentian violet, and on decolorizing with twenty-five per cent. nitric acid the tubercle bacilli, if present, will retain their

* Sternburg. *Report on Etiology, etc., of Yellow Fever.* P. 117.

† *Report on Cholera in Europe and India.* E. O. Shakespeare. P. 641. See also Brieger in *Deutsche Med. Woch.* 1887. P. 303.

stain, appearing deeply colored on a colorless ground. Of course it is then possible to bring them into greater prominence by staining the ground with a deeply contrasting color.

Aside from the re-action of the bacteria with staining re-agents, their behavior in regard to oxygen is of importance. The bacillus of tetanus grows in an atmosphere devoid of oxygen, and pure cultures may be and are best grown in hydrogen or nitrogen. This bears out our clinical experience by which we see that a deep, punctured wound is more apt to be followed by tetanus than an open one, other things being equal. The vibrios of butyric fermentation, and the putrefactive bacteria, show a marked difference in behavior, according to the amount of air present—if limited, fermentation; if abundant, putrefaction occurring. So invariable is this law, that Pasteur describes fermentation as “life without air.”

4. The final and conclusive test by which species of bacteria may be distinguished is *actual experiment on a living animal*. As this is a test of the pathogenic nature of these minute beings, it will be referred to again in another connection.

By judicious use of the various methods indicated above, the micro-organisms may be classified, and then the problem of their relation to disease confronts us. To be regarded as the cause of a disease, the suspected bacterium must fulfill the following conditions:

1. It must be present in all cases of the disease.
2. It must not be found in the body except during the course of the disease.
3. It must produce the disease when properly introduced into an animal susceptible to that particular disease.

The second of these three conditions must be interpreted with liberality, for, as was shown above, there are conditions under which the same bacterium seems to be malignant at one time and not another. It is therefore possible that a micro-organism might be in the system, and yet not produce its specific effect.

It is not my purpose to go deeply into the varieties of patho-

genic bacteria. A very few, and those few the ones of greatest practical importance, will suffice for the purpose of this paper, for I merely wish to show the manner in which these minute creatures produce specific diseases.

The most brilliant success that bacteriology has achieved, from a practical point of view, has been in the *treatment of wounds*. Tyndall made a number of experiments to show that the motes in the air were the origins of the micro-organisms found in putrescent material, the result of which experiments can best be summed up in his own words :

“Build a little chamber, and provide it with a door, windows, and window shutters; let an aperture be made in one of the shutters through which a sunbeam can pass; close the door and shutters so that no light shall enter save through this aperture. The track of the sunbeam is at first perfectly plain and vivid in the air of the room. If all disturbance of the air be avoided, the luminous track will become fainter and fainter, until at last it disappears absolutely, and no trace of the beam is to be seen. What rendered the beam visible at first? The floating dust of the air, which, when thus illuminated and observed, is as palpable to sense as dust or powder placed in the palm of the hand. In the still air, the dust gradually sinks to the floor, or sticks to the walls and ceiling, until finally, by this self-cleansing process, the air is entirely freed from mechanically suspended matter.

“Thus far, I think, we have made one footing sure. Let us proceed. Chop up a beefsteak, and allow it to remain for two or three hours just covered with warm water; you thus extract the juice of the meat in its concentrated form. By properly boiling the liquid and filtering it, you soon obtain from it a perfectly transparent beef-tea. Expose a number of vessels containing this tea to the moteless air of the chamber, and a similar number to dust-laden air. In three days every one of the latter stinks, and, with the microscope, every one of them is found swarming with the bacteria of putrefaction. After three months or three years, the beef-tea within the chamber, if properly sterilized in the first instance, will be found as sweet and clear as it was the first moment it was put in. There is absolutely no difference between the air within and the air without, save that the one is dustless and the other dust-laden. Clinch the experiment thus: Open the door of the chamber and allow the air to enter it. In three days afterward you have every vessel within the chamber swarming with bacteria, and

in a state of active putrefaction. Multiply your proof by building fifty chambers instead of one; employ every imaginable infusion of flesh, fish, fowl, and viscera, and of vegetables of various kinds; if in all of these cases you find the dust invariably producing its crop of bacteria, while neither the dustless air nor the nutritive infusion, nor both together, are ever able to produce this crop, your conclusion is simply irresistible that the dust of the air contains the germ of the crop which has appeared in your infusion. I repeat that there is no inference of experimental science more certain than this one.”—*Popular Science Monthly*, December, 1876.

Acting on these facts, and the results of Pasteur's experiments in the same direction, Lister conceived the idea that by excluding these germs from a wound, or killing them should they gain admittance, putrefactive processes would not occur in the wound, and that healing by “first intention” would occur, and so he devoted much care and study to dressings to accomplish this purpose. At first shellac and carbolized putty were used, and a spray employed to sterilize the atmosphere in the neighborhood of the wound; but experience has shown that much of the original dressing was unnecessary, and at present the dressings are much simpler, though equally effective.

The principal opponent of antisepsis is Mr. Lawson Tait. He points with just pride to results which he asserts were obtained without antisepsis, but so thorough is his asepsis, that antisepsis is unnecessary. If no micro-organism be admitted, it is obviously useless to take measures to destroy it. He uses boiling water to sterilize his instruments, sponges and dressings, and boiled water for irrigating the field of operation. Heat is one of the best of germicides, and for one using heat as a sterilizer to deride antisepsis and claim not to practice it, is remarkable. He prefers heat to chemical agents as a germicide—that is all. Would a surgeon using chloroform instead of ether be justified in saying that he did not use anaesthesia? Yet this is Tait's position.

But antiseptic surgery needs no defence at my hands; and if it did, the increased range of surgery, and the better results obtained by it, would be sufficient.

Anthrax, or malignant pustule, is a disease usually originating among cattle, and from them communicated to man. It particularly attacks wool-sorters, and usually ends in death from the many abscesses incident to the disease. The cause of this serious disorder has been definitely determined to be a bacillus found in immense numbers in the blood and tissues of those affected. This bacillus is $\frac{5}{10}$ micro-millimetres long and $\frac{1}{25}$ mm. broad. It is of great interest from a purely scientific point of view, as it illustrates many phenomena in relation to these forms of life. If the bacilli be cultivated in a liquid medium, reproduction takes place by the formation of spores, which are seen as bright oval spots marking the direction of the rods. Upon solid culture media, the rods segment transversely before giving rise to spores, the cell membrane of each section becoming the membrane of the spore, but having a small lump of protoplasm at each end, which can be stained. The precise significance of this variation is unknown.

But a still more interesting fact is that the culture media have the power of increasing or diminishing the virulence of the bacilli to a great extent. If one-third per cent. of lactic acid be added to the cultures, the virulence of the bacteria is increased two-fold, whereas cultures kept at a temperature of 107°–109° F. for three or four weeks are greatly attenuated, and a temperature of 131° F. deprives the bacilla of their virulence, though immunity may be obtained by inoculation with them. It is also found that attenuation may be obtained by passing the bacilli through various animals. Thus, if a rabbit be inoculated from a fresh culture, a guinea-pig from the rabbit, a goat from the guinea-pig, and so on, the bacilli becomes so altered as to become incapable of transmitting the disease; or, at least, will only transmit a mild variety of it. There is evidently some analogy between this attenuation and the influence of the diet of the subject alluded to above.

In regard to the mode in which the bacilli of anthrax cause death, the most plausible view, and that best supported by experimental evidence, is that advanced by Hoffa in *Die Natur des Miltzbrandgiftes*, published at Weisbaden in 1886. This

is, in brief, that the bacilli separate the complex combinations in the organism into toxic substances. He made artificial cultures with the greatest care, on sterilized meat, kept for several weeks at a temperature of 98.6° F., and attenuated the product by several methods. This attenuated product he used experimentally on frogs, mice, guinea-pigs, and rabbits, and produced symptoms of intoxication. At first, after the inoculation, increased action of the heart and acceleration of breathing was observed, then the animals became somnolent, respiration deep, slow, and irregular, pupils dilated, temperature sub-normal, diarrhœa, with bloody fæces, and speedy death. At the necropsy, the heart was contracted, blood dark-colored, and ecchymoses found on the pericardium and peritoneum. No such results followed the injection of sterilized meat-juice, and the deduction was inevitable that some ptomaine elaborated by the bacilli was the active agent.

The time at my disposal forbids me to go further into the discussion of special bacteria and their specific effects; but before closing, I wish to speak of the *bacillus of typhoid fever*. I have done some experimental work with them during the past summer, but as yet cannot say that I have accomplished anything very definite. My cultures were made from the fæces of a typhoid patient, the colonies of bacilli typhoses being isolated as well as I could isolate them by roll-cultures. I was able to produce profuse diarrhœa, and at the necropsy found the lymphatic glands swollen, but that is all. Whether the animal used (mice) are capable of taking the disease, I do not know, I can but state the facts as I found them.

